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POWER REQUIREMENTS OF ELECTRICALLY DRIVEN DAIRY MANUFACTURING EQUIPMENT

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INTRODUCTION

That the use of electrical energy in dairy manufacturing has become general in California is evident from the fact that it is used in more than 900 plants of various sizes and types operated in the state. Data show that 92 per cent of the plants use electrical energy for power; that the total horsepower of electric motors installed in all plants exceeds 73,800; that the annual power bill amounts to approximately $2,486,000.

There has been a considerable demand for information regarding the energy requirements and load characteristics of dairy manufacturing equipment, and also regarding the energy requirements of various manufacturing processes in which electrical energy is used. This information is necessary as a basis for improving the design and the operating efficiency of the machinery, and also as a basis for determining costs in cost accounting. A study has been made by the Division of Dairy Industry in which numerous laboratory and field tests have been conducted and data have been secured covering these points, with special reference to California conditions.

ENERGY REQUIREMENTS FOR DAIRY MANUFACTURING EQUIPMENT

The energy used in the processing of dairy products is an important item in the cost of manufacture. The dairy plant operator who keeps cost accounting records of this phase of his business has made a step toward greater efficiency. In order to obtain the maximum value, however, he must know the actual amount of energy consumed by each piece of his equipment and compare its performance with that of an established standard.

One purpose of this publication is to offer a suitable basis for comparison. Data were secured covering the actual energy requirements of the more important types of dairy manufacturing equip-

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ment, when used under normal conditions such as would be found in the average dairy manufacturing plant.

A summary of the data secured is shown in Table 1, which gives the name of the equipment used, the process carried on, the product treated, the rated capacity of the machine, the size of motor used, the unit of product taken as a basis for comparison, and the kilowatt hours of electrical energy used per unit of product handled. The results presented in this paper were obtained from a large number of individual trials with each machine, and for the most part from machines of average capacity. In making comparisons with equipment of sizes other than those given, one should remember that more efficient results will usually be obtained from larger equipment, and vice versa. The cost of energy used in carrying on a certain process may be calculated as illustrated in the following paragraph.

Problem:

Find the cost of electrical energy used in washing 1000 milk cans in a can washer of the type using motor-driven pumps, when electrical energy costs two cents per kilowatt hour.

Solution:

Referring to Table 1, line 10, it is found that the energy requirement for this type of washer is 3.5 kw-hr. per 100 ten-gallon cans washed. The cost of electrical energy for washing 1000 cans then, will be

$$10 \times 3.5 \times \$0.02 = \$0.70.$$

Factors Affecting Energy Consumed.—The amount of energy used by a machine is affected by its mechanical condition and by the methods used in its operation. For most economical results, all valves and pistons must be kept tight and the stuffing boxes well packed, so that they neither bind nor leak. All bearings must be properly adjusted; the chains or belts used must have the proper tension and alignment, and all moving surfaces where there is friction must be kept properly lubricated.

The machine should be operated at uniform speed and at as nearly its rated capacity as possible. Intermittent starting and stopping of a machine or process consumes energy needlessly. The operator should endeavor to turn off the power as soon as the process is completed, for motors operate very inefficiently at light load and disturb the electrical balance of the entire system. A large number of motors running idle may cause such a low power factor[2] on the system, as to bring about undue heating of those fully loaded.

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[2] Low power factor increases the current flow for a given amount of energy transmitted.

TABLE 1

ELECTRICAL ENERGY CONSUMED IN DAIRY MANUFACTURING PROCESSES

Machine	Process	Product treated	Capacity of machine	Type of machine	Unit of product treated	Average kilowatt hours used per unit of product treated
Compressor	Refrigeration		12 tons	Single cylinder, double acting	Ton refrigeration	26.000
Homogenizer	Homogenization	Ice cream mix	300 gallons per hour	Triple acting	100 pounds of mix	0.3140
Pasteurizer	Pasteurization	Milk	200 gallons	Glass enameled, propeller type agitator.	100 pounds of milk	0.1400
Pasteurizer	Pasteurization	Cream	250 gallons	Wizard—horizontal coil	100 pounds of cream	0.0493
Pasteurizer	Pasteurization	Cream	250 gallons	Vertical coil	100 pounds of cream	0.0367
Bottling machine.	Bottling	Quart bottles	60 bottles per minute	Continuous	100 quart bottles	0.0119
Churn	Churning	Cream	1800 pounds	Single roll	100 pounds of cream	0.1970
Freezer	Freezing ice cream.	Ice cream mix	40 quarts	Brine type	10 gallons of ice cream	0.5450
Can washer	Washing cans	Milk cans	600 cans per hour	Continuous steam-driven pumps*	100—10-gallon cans	0.0624
Can washer	Washing cans	Milk cans	600 cans per hour	Pumps, electrically driven	100—10-gallon cans	3.5000
Bottle washer	Washing bottles	Milk bottles	60 bottles per minute	Soaker type*	100 quart bottles	0.0585
Bottle washer	Washing bottles	Milk bottles	120 bottles per minute	Jet type, electrically driven pumps	100 quart bottles	0.1665
Cream separator	Separating cream	Whole milk	4500 pounds per hour	Centrifugal type	1000 pounds of milk	0.3050

* Carrier only, driven by electric motor.

The size of motor used should be equivalent to the power requirement of the machine driven or, in order to care for overloads, it may be a trifle oversize. Most motors are made large enough to carry a momentary overload of 100 per cent. The efficiency of a motor is highest at or very near its rated capacity, and drops off markedly at loads below one-half or above one and one-fourth of its rated horsepower.

In processes making use of electric heaters, it is very important to have all external heat radiating surfaces well insulated. It is often more economical to use large storage tanks for hot water, since a small amount of power used over a longer period of time lessens the cost of electrical energy on account of the lower power and energy rate.

OPERATING CHARACTERISTICTS OF DAIRY MANUFACTURING EQUIPMENT

The information given on the following pages deals with the operating characteristics of certain types of dairy equipment. A study of these results shows the factors that affect the power consumption and general operating characteristics of each type of equipment. It is especially important to note how by varying such factors as head-pressure of a refrigeration machine or the type of ice cream freezer, the power consumption of the process is materially changed. It is also of importance to note how the uniformity of load varies with the different machines and with various methods of operation. Uniformity of load is important from the standpoint of determining the proper size of motor to use and in assisting to balance the machine. An unbalanced condition, which usually causes a badly pulsating load, throws a severe strain upon all the operating mechanism, and therefore should be avoided.

POWER CONSUMPTION OF REFRIGERATION MACHINERY

The variation in power consumption of a twelve-ton, double-acting, compression type of refrigeration machine, when operating under various head-pressures is shown in figure 1. From an observation of the curve, it will be seen that much more power is required to drive the compressor against a head-pressure[3] of 200 pounds per square inch, than against a pressure of 150 pounds, even though the back-pressure is the same under both conditions.

[3] Head-pressure (sometimes called pressure on the high side) is the pressure in the condenser, against which the compressor must pump the refrigerating gas.

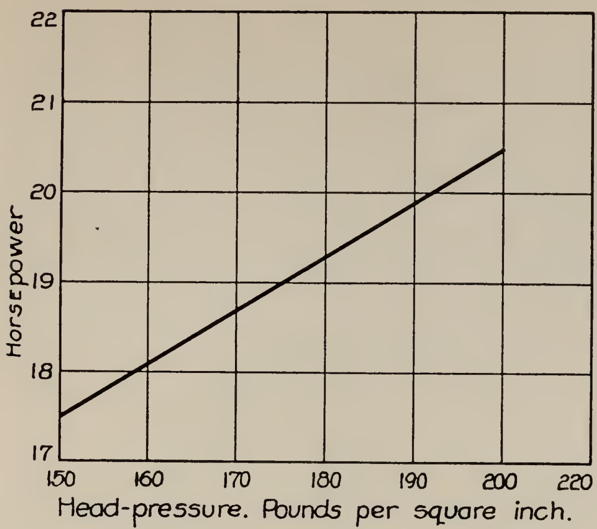

Fig. 1.—Relation of head-pressure to power requirements of refrigeration machines.

From a number of actual observations under the conditions above, the power consumption has been found to increase 16.2 per cent, with a pressure rise of 50 pounds. This increased power consumption is due partially to increased friction losses in the equipment, but principally to the greater head which must be pumped against.

The cost of energy per ton of refrigeration at the various head-pressures, when electrical energy costs two cents per kw-hr., is shown in Table 2. A comparison of results upon this basis, shows the cost per ton to be 8.8 cents greater when operating at 200 pounds head-pressure than when operating at 150 pounds.

TABLE 2

COST OF ENERGY FOR DRIVING REFRIGERATION MACHINE AS AFFECTED BY VARIATION OF THE HEAD-PRESSURE

Head-pressure, pounds per square inch	150	160	170	180	190	200
Cost of energy in cents per ton	52.4	54.5	55.2	57.0	59.2	61.2

The yearly saving on the power bill of a 50-ton refrigeration machine operating at 150 pounds as compared to 200 pounds head-pressure and with electric energy at two cents per kw-hr. may be calculated as follows:

Fifty-ton machine operating for 10 hours per day for 360 days	7,500 tons refrigeration
Cost per ton at 200 pounds pressure	61.2 cents
Cost per ton at 150 pounds pressure	52.4 cents
Cost per year at 200 pounds pressure	$4,590
Cost per year at 150 pounds	3,930
Saving per year by operating at 150 pounds head-pressure	$660

Factors Affecting the Head-pressure.—Several factors influence the head or condenser-pressure of a refrigeration machine. The most important of these are the temperature and the amount of cooling water supplied to the condenser. Other factors are the size and amount of cooling surface, the cleanliness of the condenser, and the presence of air or inert gases. It is recommended that at least two gallons of water at or below 70 degrees F. be supplied per minute, per ton of refrigerating capacity. In some sections of the country where there is a shortage of water or where it must be pumped a considerable distance, a cooling tower will be found economical. It will reduce the temperature of the water so that it may be used over and over again. The larger volume of water which is thus available for circulation, makes possible a better heat transfer from the condenser.

The condenser should be large enough to allow plenty of surface for the cooling of the ammonia. The addition of more condenser capacity will often pay for itself in a short time, through the reduction of head-pressure and the consequent saving of power. Since condenser tubes become scaled over, they should be cleaned occasionally. Instances are on record where a thorough cleaning with a rotary tube cleaner has caused a drop of 50 pounds per square inch head-pressure.

''Non-condensible''[4] gases tend to accumulate in the condenser and fill space which should be occupied by the refrigerant, thus causing an increase in the head-pressure. Non-condensing gases are removed by frequent purging,[5] or by so-called ''non-condensible gas removers.''

OPERATING CHARACTERISTICS OF CHURNS

The power characteristics of a common single-roller type churn are illustrated by the typical curve shown in figure 2. The heavy curved line A represents the average power consumed at various intervals during the churning operation. It drops somewhat after the cream has been churned for a few minutes, but rises again as the churning nears completion. One of the principal features of figure 2 is shown by the shaded area. The extremes of this area represent the momentary variation in the pull on the motor, as measured by an indicating watt-meter. Twenty-four minutes after starting the pull varied from zero to 5¼ horsepower. At one instant the motor was drawing 5¼ horsepower from the line and at the next was drawing none. It is readily seen that such an unbalanced load not only

[4] ''Non-condensible gases'' are those such as air, nitrogen and hydrogen, which collect in a refrigeration plant and are not condensed at the usual operating pressures and temperatures.

[5] Purging is the operation of blowing off gases from the condenser.

throws a severe strain upon the driving motor and gearing, but also upon the churn itself. To eliminate this unsatisfactory condition, designers of churns should produce a better balanced and smoother operating piece of equipment. The use of counterbalances would help to make the load more uniform. The average power consumption for the entire churning process is indicated by the heavy broken line marked "AVERAGE" in figure 2. This is the value which should really determine the size of motor required, provided that the momentary load is never so large as to stall the motor or greatly reduce its speed.

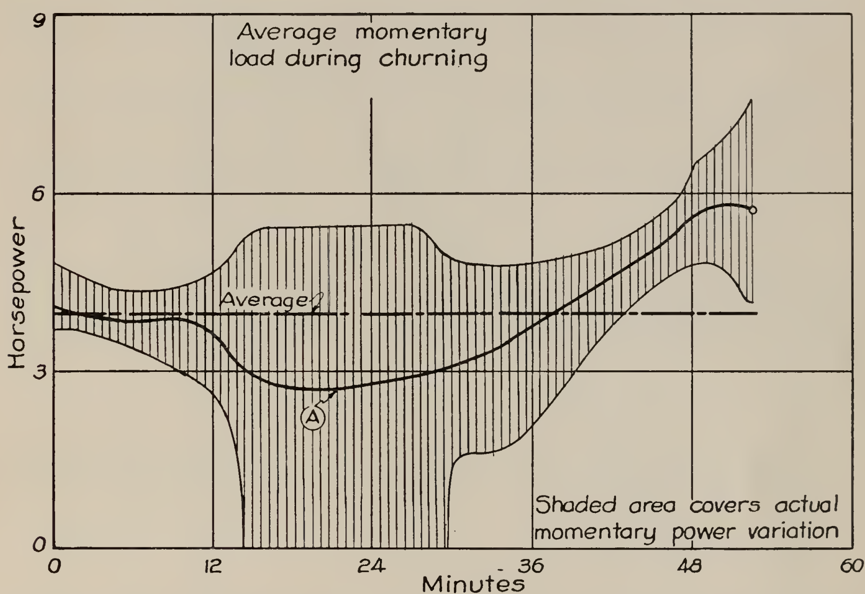

Fig. 2.—Power consumption of a typical churn, showing variation during the churning process.

OPERATING CHARACTERISTICS OF ICE CREAM FREEZERS

Method of Freezing.—The power characteristics of ice cream freezers were found to vary considerably with the different types of machines, methods of freezing, and kinds of mixes. The data collected show that there can be no general recommendation of a definite size of motor for all freezers of a particular capacity. It shows also the necessity of the operator's keeping in close touch with the freezing process, and emphasizes the need for some method of indicating to the operator the exact state of the freezing process at all times.

The simplest method of making ice cream is to freeze the mix to a given stiffness and then turn off the freezing medium and whip until

the desired amount of air is incorporated. Figure 3 shows the variation in power consumed by a standard 40-quart freezer with the horizontal blade-type of dasher, so operated. With this method of freezing, it is apparent that the power consumption of the motor increases gradually, up to the point X where the freezing medium is turned off, after which there is a decrease down to the point Y, where

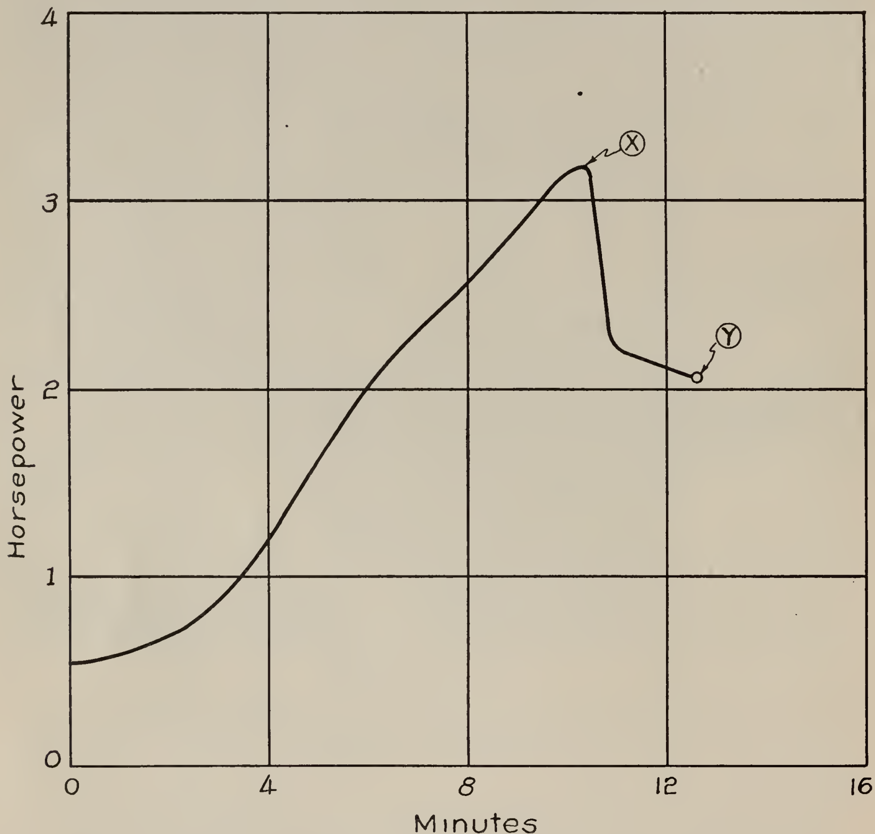

Fig. 3.—Power consumption of a 40-quart freezer when the "freeze and whip" method of freezing is used.

the ice cream is drawn from the freezer. The increase in the power consumed is caused for the most part by the increasing stiffness of the mix as it becomes colder and by the increase in friction of the driving mechanism. The two rates of decrease that are shown are both due to lessened resistance to the rotating blades of the dasher. The first or more rapid decrease, coming just after the freezing medium is turned off, results from the softening of the frozen film, which the dasher has been scraping from the sides of the freezer. The further or second

one, is undoubtedly caused by the thinning of the mix and the incorporation of air. Since there are a number of factors which affect the shape of the curve, no two freezers, even though they be similar, have been found to give identical curves. Some of the influencing factors are: change in composition of mix, brine temperature, and method of homogenization. One point worthy of special note is the effect of a leaky brine valve. This will ordinarily prevent the drop in power consumption after the freezing medium has apparently been turned off. A leaky brine valve may usually be recognized by the failure of

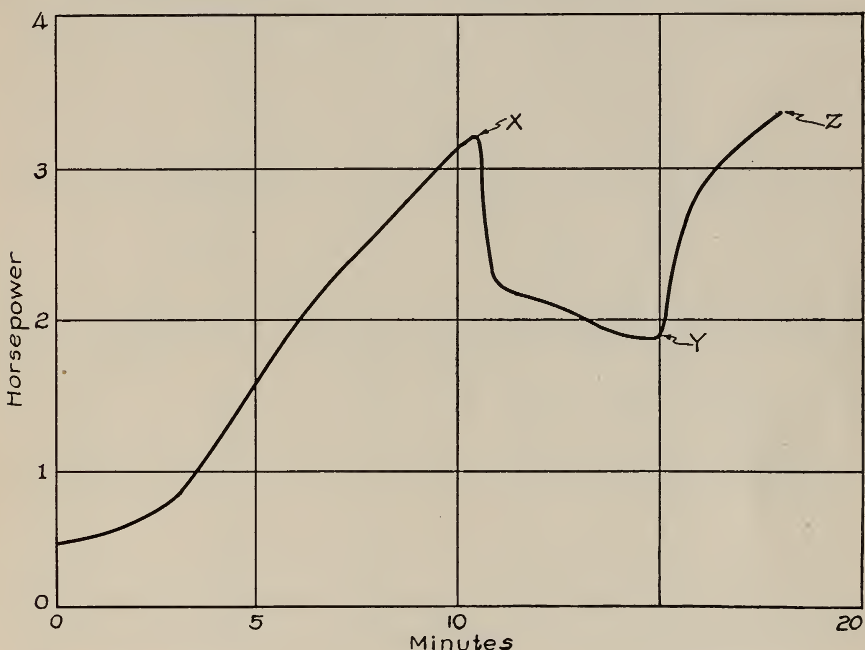

Fig. 4.—Power consumption of a 40-quart freezer when the "freezing back" method of freezing is used.

the pointer of an indicating ammeter or watt-meter, connected in the motor circuit, to drop back. An exception to this rule should be noted in the case of some freezers which employ the squirrel-cage type of beater and in which the power consumption does not materially decrease after the freezing medium is turned off. A second exception is in the case of a freezer operated in such a manner that the ice cream is "whipped" as it is frozen, the freezing medium not being turned off until the freezing operation is finished.

The variation in power consumption of ice cream freezers when the "freeze-back" method was used, is shown in figure 4. The curve with this method, was similar to that obtained with the first method

described, until the point was reached where the cream would be drawn, if the first method of freezing were being followed. With the second method however, the "whipping" was continued, and the power consumption decreased still farther down to point Y, at which time the mix had absorbed more air than was desired in the finished product. In order to drive this excess air from the mix, the freezing medium was again turned on at the point Y; the frozen film was again built up on the inside of the freezer barrel and the cream became stiffer. There was an accompanying increase in the power consumption up to the point Z, at which time the mix was drawn from the

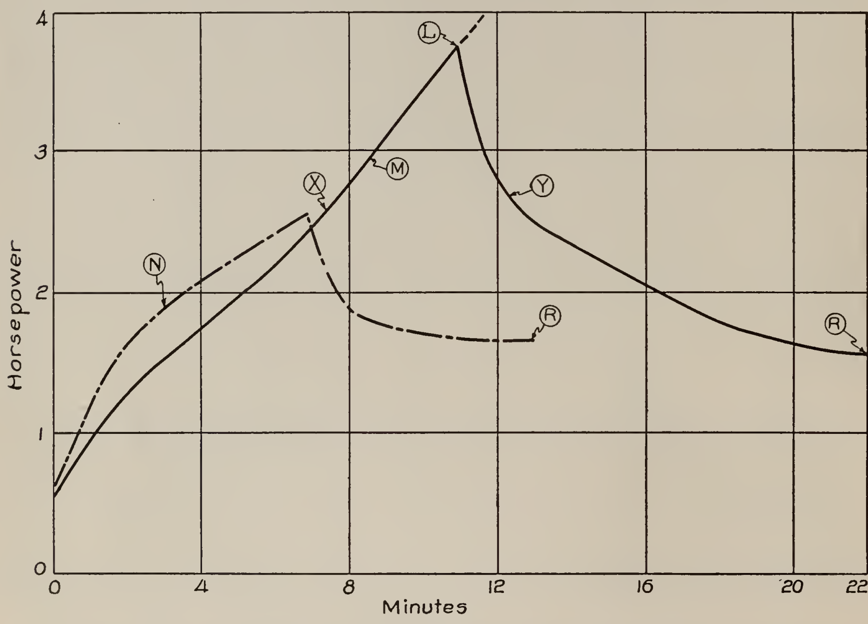

Fig. 5.—Effect of stiffness to which ice cream is frozen, upon power consumed by the freezer motor.

freezer. A comparison of the two methods shows that the former places a smaller average load on the freezer motor and that a shorter period of time is required. The first method is, therefore, preferable from the standpoint of economy of operation, both time and energy consumed being considered.

Effect of Freezing to Various Degrees of Stiffness.—Some plants experience a considerable loss in quality of ice cream and in time and energy consumed because the operators fail to control properly the stiffness to which the mix is frozen before it is drawn from the freezer. Figure 5 presents graphically the effect upon the power consumption of freezing to various degrees of stiffness, a standard 40-quart brine-

type freezer being used. Curve N shows the power consumed while freezing the mix to an ordinary consistency. Curve M shows that consumed while freezing to a very stiff consistency. It is apparent that the latter method required considerably more time, energy, and power.

Another point to be considered in each method is that of the peak load. The peak load L as shown by curve M is very much greater than that shown by curve N and emphasizes the fact that a greater strain is placed upon the motor and driving mechanism as a result of

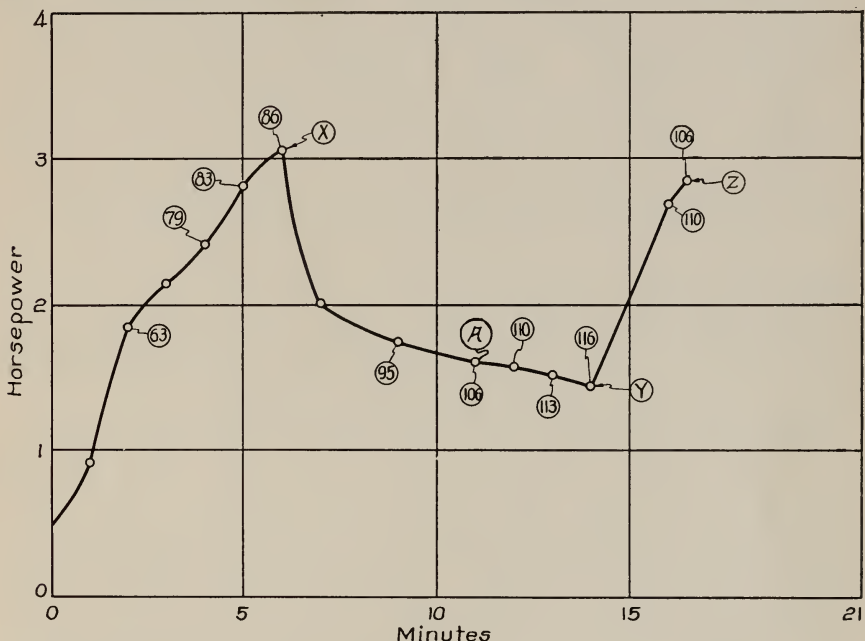

Fig. 6.—Relation of power consumption of the freezer to the stage of freezing process, with a typical freezer.

freezing the ice cream too stiff. Curve M shows results which might be obtained should the operator neglect to turn off the freezing medium at the proper time. Under such conditions the motor is likely to "burn out." Moreover, aside from the effect upon the equipment itself, the product lacks uniformity, a quality highly desirable in ice cream.

Effect of Stage of the Freezing Process Upon the Power Consumption of the Freezer.—The relation of the power consumed by ice cream freezers to the stage of the freezing process, and especially to the amount of air contained in the mix at different intervals, has received the attention of ice cream manufacturers for some time, as it offers

possibilities for the control of the freezing process. The relationship between the power consumption and over-run or yield of a 40-quart horizontal brine-type freezer is shown in a typical curve, figure 6. Inspection of the curve shows that the percentage of air, determined by weighing and shown by the figures within the circles gradually increased from 63 to 86 per cent, at the time the freezing medium was turned off at point X. During this period, there was also a gradual increase in the power consumption. As the point X on the chart was reached, the freezing medium was turned off and the power consumption dropped, as was described under "Methods of Freezing." The percentage of air absorbed by the ice cream increased as the power consumption decreased. At point Y the brine was again turned on and the result was an increase in the power consumption with a corresponding decrease in the amount of air held in the mix. The ice cream could have been drawn from the freezer at either of the two points A or Z, each of which shows an over-run of 106 per cent. There would have been a slight difference in the air content of the drawn product, however, because of the fact that at point A the air content was increasing, while at point Z it was decreasing.

Among the other factors affecting this relationship between the power consumed and the stage of the freezing process are composition of mix, temperature of brine, and type of freezer.

The Effect of the Kind of Ice Cream Frozen Upon Power Consumption of the Freezer.—Freezing various kinds of ice cream seems to make a difference in the power consumption of freezers. Table 3 shows results obtained from the study of the operation of a 40-quart standard dasher, horizontal, brine-type of freezer, operating under regular commercial conditions, and using the "freeze back"[6] method of freezing. The conditions were all comparable as to brine temperature, speed of dasher, and amount of mix. The plain vanilla ice cream required the least amount of time, or 16.8 minutes, while the strawberry was next with 22.1 minutes. The chocolate required the most time, with 29 minutes. It should be mentioned in this connection that the time required for the chocolate ice cream could have been reduced somewhat by cooling the syrup to a lower temperature before adding it to the mix. This is an important point in the manufacture of any ice cream, in which a part of the ingredients are added to the main batch during the freezing process, as the addition of a warm syrup, for instance, causes a breaking down of some of the air cells, with a consequent loss of time in freezing. Results show a longer than average time-requirement, which was due to the small volume of brine

[6] See page 11.

available for this particular installation, and to the use of the "freeze-back" method of freezing.

The average power required during the freezing process was 1521 watts for the vanila ice cream, 1682 watts for the chocolate, and 1767 watts for the strawberry. Although the maximum power consumption was about the same for each kind, the average was higher for the strawberry and chocolate because of the longer period of whipping after the mix was partly frozen. The freezing of puddings requires considerably more power than either chocolate or strawberry ice cream because of the greater stiffness of the mix.

TABLE 3

Effect of Kind of Ice Cream upon Power Consumption of the Freezer

Kind of ice cream	Minutes to freeze	Average watts	Maximum watts	Kw-hr. per 10 gallons of ice cream
Vanilla	16.8	1521	2260	.4258
Chocolate	29.0	1628	2408	.8120
Strawberry	22.1	1767	2284	.6508

* Freezing time was slightly high on account of small volume of brine available in this particular plant and the use of the "freeze back" method of freezing.

The energy consumption per batch was .4258 kw-hr. for the vanilla ice cream, .6508 kw-hr. for the strawberry, and .8120 kw-hr. for the chocolate.

Variation in the Power Required to Drive Different Freezers.—A number of factors enter into the design of the freezer itself, all of which affect its power consumption. Among the most important of these are the speed and type of dasher. Table 4 shows results obtained from two commercial machines of 40 quarts capacity operating under similar conditions. The first machine, which was of the vertical type, was driven at a speed of 225 r.p.m., and used what is known as the squirrel-cage type of dasher, in which the rotating element carries a

TABLE 4

Variation in the Power Required to Drive Different Types of Freezers

Kind of dasher	Speed of dasher, r.p.m.	Temperature of brine, °F.	Time for freezing, minutes	Average watts consumec	Maximum watts consumec	Kw-hr. per 10 gallons of ice cream	Average H.P.	Size motor, H.P.
High speed vertical squirrel-cage	225	6°	12.8	2454	3480	.522	3.28	3
Horizontal, blade-and-paddle	165	6°	12.3	1360.8	1982	.279	1.83	3

number of rods held together in the form of the traditional squirrel cage. The second, which was of the horizontal type, was driven at a speed of 165 r.p.m. and was equipped with a blade-and-paddle type of dasher. Both machines used the same brine and mix, and were operated simultaneously. The first machine used almost twice as much energy per batch of cream frozen as did the second. The time required for each was practically the same, being one-half minute less for the

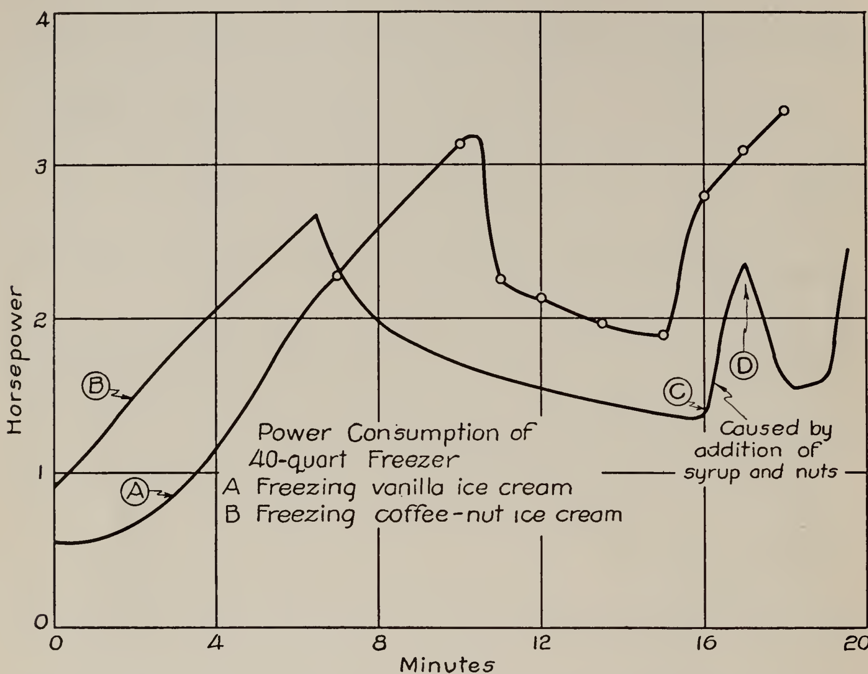

Fig. 7.—Effect upon power consumption of adding ingredients to the mix during the freezing process.

horizontal standard-blade machine. These data show that the commercial type freezers of the same capacity vary greatly in the power required to operate them, and that no specified size of motor can be recommended as best for all makes and types.

Effect of Addition of Ingredients to Mix upon the Power Consumption of the Freezer.—It is desirable in the freezing of certain types of ice cream, such as strawberry, chocolate, or puddings, to add a part of the ingredients to the mix after the mix is partly frozen. This affects the power consumption in several respects. First, if the ingredient added is cold and viscous, it will momentarily increase the power consumption, and also the total energy consumed per batch. This accounts in part for the higher energy requirement for freezing

such ice creams. This condition is illustrated in figure 7, in which the rise C–D in curve B was caused by the addition of a thick, cold, syrup. The third rise in this curve resulted when the brine was turned on. Curve A shows the shape of the curve when no ingredient was added during the freezing process, other conditions being similar.

If the ingredient is hot or warm when added, as is sometimes the case in the manufacture of chocolate ice cream, the power consumption may drop momentarily, on account of a thinning of the mix from the heat absorbed. This is undesirable, as was heretofore explained.

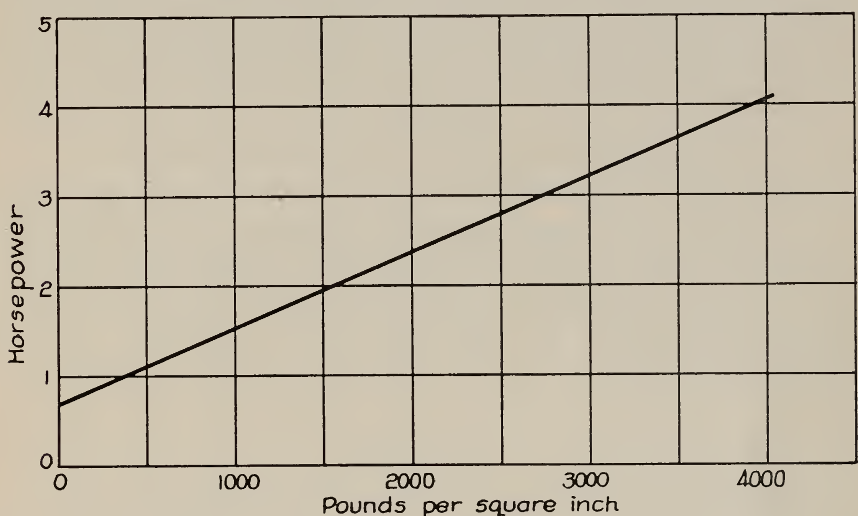

Fig. 8.—Relation of operating pressure to power requirements of a typical homogenizer.

OPERATING CHARACTERISTICS OF HOMOGENIZERS

The power consumption of homogenizers varied almost directly with changes of pressure at which the machine operated. Figure 8 shows the variation in the power consumption of a 100-gallon-per-hour homogenizer, equipped with a 5-horsepower motor and operated at constant speed and capacity. The power consumption increased in direct proportion to the increase in pressure on the homogenizer. The amount of power used was the same, whether ice cream mix or water was passed through the homogenizer. It is evident that the power consumption could be taken as an index of the pressure at which the machine is working. Variations of the flow of the mix through the homogenizer, due to poorly fitting or leaky valves may be detected by the vibration of the power indicator needle.

OPERATING CHARACTERISTICS OF ELECTRIC DAIRY STERILIZERS

The common type of electric dairy sterilizer used mostly for sterilizing milk pails, milking machine parts, and other similar equipment is also used to some extent in small creameries and ice cream plants.

The apparatus, as usually constructed, consists of an inclosed tank, in which a small amount of water is placed, and an electric heating element of from three to five kilowatt capacity, laid in or attached to the bottom in such a manner that the water surrounds the heating element. When the current is turned on, the water is heated and steam generated. The steam rises and envelops the utensils to be sterilized, which are contained in the tank. Practical sterilization is accomplished by holding the equipment at a temperature of 210° F. for fifteen or twenty minutes, but satisfactory results can often be secured by heating to a temperature of 170° F. for fifteen minutes, the minimum specified in the California dairy law.

TABLE 5

OPERATING CHARACTERISTICS OF DAIRY FARM STERILIZERS

Description of sterilizer	Water used, pounds	Minutes reach 170° F.	Minutes reach 210° F.	Minutes above 170° F.	Watts demand	Kw-hr. per batch	Cost to heat sterilizer to 210° F. at 2.5 cents per kw-hr.
5-kilowatt heater, uninsulated	50	26.50	36.50	32.50	5736	3.48	8.7
5-kilowatt heater, uninsulated	17	14.12	24.64	22.11	5716	2.35	5.87
5-kilowatt heater, uninsulated	10	11.30	22.50	21.42	5607	2.10	5.25
5-kilowatt heater, insulated bottom	17	13.46	23.83	28.00	5614	2.23	5.57
5-kilowatt heater, insulated bottom and top	17	13.80	21.78	33.13	5557	2.02	5.05
3-kilowatt heater, plain top	17	29.22	54.10	42.51	2883	2.60	6.50
3-kilowatt heater, insulated bottom and top	17	29.00	46.70	47.07	2941	2.29	5.73

The effect of the amount of water, the size of heater, and the quality of insulation upon the operating characteristics are shown briefly in Table 5. A comparison of lines 1, 2, and 3, shows that the energy consumed per batch was reduced from 3.48 kw-hr. to 2.10 kw-hr. by using only ten pounds of water instead of fifty in the sterilizer; that at the same time there was a corresponding decrease of 15.2 minutes in the time required to reach 170 degrees F.

The effect of insulation is evident from a comparison of lines 2 and 5, which refer to data obtained from uninsulated and insulated

sterilizers of four-can capacity, each being equipped with a 5-kilowatt heater. The energy consumption was reduced by the use of insulation from 2.35 kw-hr. to 2.02 kw-hr. per batch. One of the most important advantages of insulation is apparent in line five, which shows the time during which the sterilizer temperature was above 170 degrees F. This was 33.11 minutes for the insulated sterilizer and 22.11 minutes for the uninsulated one, the power being turned off in each case, at the time the temperature reached 210 degrees F. and the cover remaining in place. The advantage of using a large heating element is shown in lines 5 and 7. The 5-kilowatt heater required 21.78 minutes as compared with 46.7 minutes for the 3-kilowatt one, under similar conditions. The energy consumed per batch sterilized was 2.02 kw-hr. and 2.29 kw-hr., respectively. It is evident that the 5-kilowatt heater gave sufficient heat to care for the extra requirement during cold weather.

An automatic thermostate is a very desirable accessory for use with electric sterilizers, as its use makes certain that the correct temperature is reached and maintained for the proper length of time. It also serves as a protection to the heating element, in case the operator should neglect to turn off the power, and it saves on the cost of energy, since it turns off the power automatically as soon as the required temperature is reached.

SUMMARY

1. The electrical energy consumed by dairy manufacturing equipment may be determined by the use of suitable instruments, and from the data secured, the cost of energy used in the processing of dairy products may be accurately calculated.

2. Increased efficiency of operation may be brought about by a thorough study of the power requirement of a process such as the freezing of ice cream and by an elimination of those conditions which cause loss of power and energy.

3. A basis for comparison, as for instance, the energy consumed per hundred gallons of milk pasteurized, together with a standard of operation, which sets a certain number of kilowatt-hours per unit of product treated, is useful in analyzing and comparing the cost of operation of equipment.

4. The power requirements and energy consumption of a machine are largely affected by conditions under the control of the operator. Careful attention to maintaining the equipment in good condition, operating it to capacity and using proper methods, will give most efficient results.

5. Careful selection of the proper size and type of equipment is important, if best results are to be secured.

6. In the operation of a medium size refrigeration machine under normal conditions, a saving of 16 per cent in the cost of power may be expected, when the head-pressure is maintained at 150 pounds instead of 200 pounds per square inch.

7. The proper balancing of such equipment as churns, will reduce strains in the motor and driving mechanism and will result in more economical operation.

8. No definite size of motor can be recommended for all types of ice cream freezers, as a large variation in power consumption is found with the different types as well as with various methods of freezing and kinds of ice cream manufactured.

9. The stiffness to which ice cream is frozen should be closely controlled in order to prevent overloads upon the motor and driving mechanism, to reduce the cost of operation, and to secure uniformity of product.

10. The relationship between the power consumption of the freezer motor and the stage of the freezing process is very close with many types of freezers. It differs in individual machines and is affected somewhat by variations in kind of mix, age of mix, ingredients of mix, and brine temperature.

11. Electrically heated dairy sterilizers are practical and economical if properly designed and operated. The sterilizer should be safe to operate when a small amount of water is used. For best results it should be insulated with a double-walled air space and be equipped with a reliable thermostat or time switch.

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